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Solid state bio methane production from vegetable wastes Current state and perception

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ABSTRACT

The energy crisis and climate change are being the global challenge for the present debate since the world is in need of a green, efficient, carbon-neutral energy source to replace fossil fuels. Bio- gas, produced by biomethanation from organic materials, contributes to durable, reliable and renewable energy. Production of bio methane from vegetable wastes provides a flexible carrier for renewable energy; methane can be used as a substitute fuel for both heat and power production. In this context, the Indian Government invited the support of the private sectors as before, for the development and utilization of Eco-friendly new and renewable sources of energy to cover the demand. The paper also reviews the current state of vegetables purposes for bio methane production, including their preparation methods and performance. The vegetable wastes for bio methane production are presented and their main advantages described in comparison with the other available method of mixture of vegetable wastes for methane production. The waste generated may cause health hazards, so, setting up a waste treatment plant based on biomethanation process is the solution to use the technology to generate electricity.

Contents

1. Introduction

The energy sector has been playing an important role in the environment of the global economy as well as the socio economic development. The world energy consumption is growing at the

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rate of 2.3% per year. The Energy Information Administration (EIA), estimated that the primary sources of energy consisted of petroleum 36.0%, coal 27.4% and amounting to 86.4% share for fossil fuels in primary energy consumption in the world [1]. The global energy demand for non-renewable resource created approximately 39,375 exa joule ($= 10^{18}$ joule) focusing on the current scenario the economically improved energy demand is growing approximately around 88% of demand on the fossil fuels. With current scenario energy calamity and change in climate are key issues all over the world. There will be a severe demand for energy in the next few decades [2]. In this time, concentrations of greenhouse gases in the atmosphere are increasing rapidly, with fossil fuel-derived CO_2 emissions. In order to decrease the global warming and climate change impacts, CO_2 emissions must be below the part of global emission levels of 1990 [3].

As fossil fuel resources are limited and their demand is high, this gap would be met with the energy generation resources. One of the feasible renewable energy sources in support of India is from biomass.

Biomass availability in the country is high as 150 tons per annum. Production of biomass would slow down the climate change, that contributes to reduce the greenhouse emissions [4]. The use of fossil fuel is an important energy source for global climate change, environmental degradation and human health problems [5]. Global climate change will predictably show the way to drought, flooding, increases in hurricanes and tornadoes and possibly failures on global warming [6]. Security of energy supply, especially sustainable energy and reduction of priorities are the agenda in worldwide.

In today's world, there has been a shift in focus to renew supplies from wastes, which are found in abundance as a by-product of any process. India's population is widely expanding. In lieu of this, it is appropriate to conceive the fact of waste generation [7]. Liveliness is an essential need for human existence. Scarcity of energy through fast depletion of fossil fuels and the increase in requirement for energy. India ranks sixth in the world for energy demand with total energy consumption of around 480.4 million tonnes, of that 46% are from biomass energy [8] and accounting for 3.5% of world commercial energy demand. In recent times when fossil fuels are gradually depleting in addition to rising costs and instability in the developed countries, renewable energy has become the best alternatives for sustainable energy development [9–10].

2. Biomethanation process

2.1. Anaerobic digestion

In the bio-methanation process, the organic waste is converted into methane and enriched manure by a large consortium of microorganisms in the absence of air, also known as anaerobic digestion [11]. Anaerobic digestion is a biological process in which untreated material is decayed by bacteria in the lack of air to yield methane and carbon dioxide. The universal technology of anaerobic digestion of complex organic matter is well known municipal and industrial waste treatment to stabilize organic wastes. The anaerobic process is more beneficial because the aerobic method in organic waste treatment and the high degree of waste stabilization, low manufacture of excess biological sludge, low nutrient prerequisite and high production of methane gas [12].

Anaerobic digestion (AD) is a process in which the microorganisms break down the biodegradable material in the absence of oxygen. Anaerobic digestion may be used to treat various organic wastes and recover bio-energy in the form of biogas, that contains mainly CH_4 and CO_2. Methane may be a source of renewable energy producing electricity in combined with heat and power sectors [13]. The Organic Loading Rate (OLR) and hydraulic retention time are two major parameters purposes for sizing the digester and their optimum values are specific to the substrate as well as the operating temperature of digester [14]. Several studies have been conducted by many researchers to increase biogas yield from biomethanation of wastes. An effort to improve biomass conversion efficiency and biogas yield by using different pre-treatment methods [15–17], optimization of biomethanation fresh water hyacinth [18]; and effects of particle size, plant nitrogen content and inoculum volume [19].

2.2. Digester plants

Digester plants are constructed of a 55-gallon plastic drum laid horizontally at 15°F, plumbed with an inlet, and two outlets for wasting out light and heavy solids. The digests are all insulated temperatures maintained at approximately 100°F. Surface to volume ratio for the fixed-film digester was approximately 45 m^3 whereas the same ratio for the control was roughly 9 m^3. Fed material was agitated and screened through a 1.5" × 2.5" mesh to remove large solid particles over 1.5". The loading rate was determined by measuring a set quantity of fresh vegetable waste loaded daily into individual tanks, indicated by gradually on floating depth indicators. Biogas production, using a water displacement device designed and carbon dioxide content, recorded daily. Biomethanation is a feasible and effective method of treatment of vegetable waste generated. Vegetable wastes are solid organic waste having high calorific value and nutritive value to microbes that's why the efficiency of methane production be increased by higher order [20]. The waste causes health hazards, and also a risk of epidemic.

3. Different vegetable wastes and their methane yields

Most of the researchers [21–30], have noted down that the Municipal Solid Waste (MSW) generation rates in the small towns are lower than those of major cities, and the per capita pace of MSW in India ranges at 0.2 to 0.5 kg/day. In 1980, Stewart described the potential use of oats, grass and straw in New Zealand, results methane yields of 170–280 $m^3.t-1$ TS [72]. Even water hyacinths and fresh water algae were shown to result in medium methane yields choose between 150–240 $m^3.t-1$ TS. Recent German practical experience showed mean methane yields of 348 m^3/t VS for maize and 380 m^3/t VS for barley [31].

Fruits and Vegetable waste were an aerobically digested in a microbiological foments laboratory scale reactor at mesophilic conditions. Each has the biogas yield as 0.429–0.568 L/g VS fed. [32]; and fruit waste the yield ranged from 0.18–0.732 vegetable waste 0.19–0.4 L/g VS added [33], 0.2–0.63 L/g of VS added [34], [35] checked the feasibility of using 2.5 liter capacity of amber colored bottle for the production of biogas 9.22 L/kg TS added to banana waste and 1.69 L/kg TS added on coir pith. An organic fraction of municipal solid waste uses a minimum production of biogas on 5 liter capacity of laboratory scale digester [36]. Researchers have reported that the biogas yield of 0.36 L/g VS fed. The municipal garbage for the production of biogas of 0.485–0.5 L/g VS fed was used normally [37].

The studies showed that the maximum biogas yields sources such as Korean food waste [38], Pineapple processing waste [39], Mango peel [40], Banana and pineapple waste [41], Potato waste and sugar beet leaves [42], Banana stem waste [43], Vegetable waste [44]. Anaerobic co-digestion of grass silage, sugar beet tops and oat straw with cow manure was evaluated by [69] in semi-continuously fed laboratory. The highest specific methane

yields of 268, 229 and 213 lCH_4 kg^{-1} VS added in co-digestion of cow manure with grass, sugar beet tops and straw, respectively, were obtained when feed with 30% of yield in the feedstock. Wastes as Banana stem, Cabbage and Ladies finger are aerobically digested in a scale reactor at mesophilic conditions. The study reports that the standard methane substance in the biogas was 65% and also the methane yield was 0.3871 CH_4/g [45].Rice and wheat straw added to cattle dung slurry and digested aerobically, they have produced gas increased from 176 to 331 l/kg total solids with 100% rice straw and to 194 l/kg total solids with 40% wheat straw [46–47].

Vegetable wastes such as pumpkin, brinjal and cabbage yield a minimum production of Protease by fermentation sugar mill press mud waste [29] sings aspergillusniger. The paper reported that about 0.787 U, 0.627 U and 0.886 U of protease per gram of substrate respectively [48]. The substrate concentration of biomethanation of water hyacinth was carried out for 60 days at mesophilic condition by various the substrate concentration from 3% to 11% in 250 ml biodigesters. The digester with 7% substrate concentration produced maximum biogas of 0.289 l (g VS)-1 and kinetic parameters P, Rm and λ were 0.309 l (g VS)-1; 0.0157 l (g VS)-1d-1 and 27.337 days respectively [49].The investigation of banana peels [50], higher rate of degradation and showed a high biogas yield of 400 ml/g. TS. The rapid degradation of banana peels, the biogas production extends over a 30 d period. This investigation requires clear identification that on which stage of anaerobic digestion is retarded [51].The anaerobic batch digestion tested for FVW [51]; under both mesophilic and thermophilic conditions. The results showed that, under mesophilic and thermophilic conditions, the mixture of vegetable wastes was quickly digested, and the first- order kinetic constant around 8.4×10^{-3}–4.1×10^{-3} 1/h g_{vss} was estimated for these materials [52].

The gas production was consists 50% of cow dung (1:1) and increasing the cow dung proportion with vegetable waste gas generation decreases beyond the 50%. Hence for vegetable waste cow dung should be added with the same percentage for optimum gas generation and each have added to stream to dilute the organic substances and to increase the breeding of micro-organism. If the fruit waste is lesser degradable it needs the double amount of cow dung to digest it properly and increasing the gas yield [10]. The COD/N ratio of FVW is balanced, being around 100/4 and therefore, no nitrogen was added to the reactors. In fact the optimum C: N ratio for microbial activity involved in bioconversion of vegetable biomasses to methane is 100–128:4 [53].In current years, greater awareness is being known to treat the wastes chemically or biologically to get useful by-product before the end of disposal. For many reasons the anaerobic act of fruit wastes to generate biogas has been absorbed reasonable interest of researchers. The study reveals that on anaerobic treatment of food dealing out wastes [54], Wastes of human origin [55].

4. Analytical methods

4.1. India Growth on Fruits and Vegetable Production

India is a second largest producer of Fruits and Vegetables in the humanity.It contributes as regards 10% and 14% of Fruit and Vegetable. Vegetable Wastes are created by harvesting, transportation, storage, marketing and processing. India produces 150 million tonnes of fruits and vegetables and generates 50 million tonnes of wastes per annum. Therefore it becomes necessary to develop appropriate waste treatment technology for vegetable wastes to minimize green-house gas emission [67]. In accordance with the fast growing population, the demand for energy and the discharge of waste are increasing day by day. To overcome the energy crisis, the renewable energy source has been the remedy as of now.

Anaerobic Digestion is a biological process that occurs naturally when bacteria breaks down of organic matter into biogas with no oxygen. It is effectively a controlled and enclosed version. Anaerobic Digestion produces 60% methane and 40% carbon dioxide (CO_2). It can be burned to produce heat or electricity. If it is used to generate electricity the biogas needs to be cultured and then power the AD process or be supplied to the national grid and for homes [70].

4.2. Vegetable waste as a substrate for biomethanation

The vegetables are cultivated seasonally and the waste generated varies considerably in quantity and composition. Therefore it is necessary to study the effects of variation in the composition of vegetable wastes on the performance of anaerobic digestion process [71]. Generation of energy from waste is beneficial in many ways. It is almost suitable for eco-friendly waste disposal and also for energy generation. To reduce the harmful emissions of carbon dioxide (CO_2) released during the production of electricity, there has been an increasing focus on sources of renewable energy, such as biomass. Developing a biomethanation process for several kinds of substrate, parameters, designs and the quality of the substrate for evolving a technology process.

4.3. Availability of vegetable waste

All cities, districts and tensile have vegetable market that produces plenty of vegetable waste irrespective of the size of the market. These wastes are to be weigh to 50 tons. Thus, the huge quantity of such vegetable waste is being fashioned daily. In India, around 400 districts with 4000 towns and market places are having large vegetable markets. Approximately the total amounts of vegetable wastes produced around 50,000 tonnes at all these places. A ton of vegetable waste produced was about 90 Cu M of biogas per day If a hardly any thousand biogas plant possibly to be installed, this waste could be an important source of biogas. It will therefore be useful to expand an expertise for the make use of this substrate, pleasing into reflection its features. The input capacity of the future plant was proposed to be about fifteen tonne of vegetable waste per day. The proposed study on biogas plant can be established in the market yard in the year 2015.

4.4. Characteristics of vegetable waste

Vegetable waste is generally perished or bungled vegetable, unfit for individual consumption. This material is naturally high in tough content. In the market, the composed waste material typically varies from street sweepings and dead trash as rags, metals etc. It is necessary to have an arrangement of the vegetable waste component is detached. Besides, these vegetables are usually in diverse sizes, shapes and forms. Each needed to be cut into smaller pieces to form slurry. Vegetable waste has a dampness content of around 89% and 75% of solids present are volatile solids. The carbon:

Table 1
General Characteristics of vegetable waste.

S. No.	Parameters	Values
1.	pH	7
2.	Total solids (mg/L)	9933
3.	Volatile solids (mg/L)	4880
4.	Total dissolved solids (mg/L)	5590
5.	BOD (mg/L)	1200
6.	COD (mg/L)	3000
7.	Total organic carbon (mg/L)	1120

Table 2
Performance of biomethanation plant at CMDA (K. Sri Bala Kameswari, et al., 2007).

Sl. No	Description	Designed Parameters	Average Performance Observed
1	Throughput capacity	30 tonnes per day	30 tonnes per day
2	Total and Volatile Solids Content Total Solids Volatile Solids	25%–7.5 TPD 74%–5.7 TPD	9%–2.85 TPD 75%–2.16 TPD
3	Average Gas Production	2500 cum/day	1143 cum/day
4	Specific Gas Production	0.44 m^3/kg VS fed	0.53 m^3/kg VS fed
5	Specific Power Generation	0.44 m^3/kg VS fed biogas	1.8 kwh/m^3 of biogas
6	Power Generation	5250 kwh/d	2047 kwh/d
7	Net Power Export	4780 kwh/d	1279 kwh/d
8	Power Consumption by the Plant	470 kwh/d	768 kwh/d
9	Additional power drawn from TNEB	–	377 kwh/d

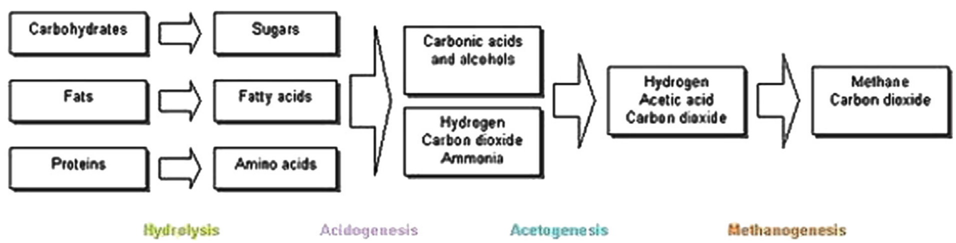

Fig. 1. Different stages of the Biomethanation Process [18].

nitrogen ratio of the mixed waste could be around 20:1 or 30:1. The process undergo with the physical and chemical characteristics. The raw material vegetable slurry is collected from a biomethanation plant for vegetable wastes. The sample is analysed for total solids, volatile solids, total dissolved solids, Organic loading rate(OLR), Oxidation Reduction potential (ORP), Hydraulic Retention time (HRS), Temperature i.e. Mesophilic (30–35 °C) BOD and total organic carbon using standard methods [56]. COD as biodegradable COD be determined using standard methods. The pH of the slurry is measured using a digital pH meter. The characteristic of the vegetable waste is given in Tables 1 and 2.

5. The Biochemical Process of Methane Production

Methane production rate is determined in different organic loading range. The kinetics of the process have been studied using first order rate equation and reported. The complete degradation of complex organic matter into methane and carbon dioxide requires the involvement of various microorganisms. The organization of anaerobic bacteria into different tropic groups that do specific metabolic transformations during the degradation of organic matter has been proposed by various investigators [57–59].

Methane fermentation is a composite process, and it is alienated into four phases: hydrolysis, acidogenesis, acetogenesis and methanation as shown in Fig. 1. The individual humiliation steps are carried out by different group of microorganisms, which moderately stand in syntrophic interrelation and rest with diverse needs on atmosphere [60]. Hydrolyzing and fermenting microorganisms are responsible for producing mainly the stuffing of acetate and hydrogen and changing amounts of unstable fatty acids such as propionate and butyrate. Hydrolytic micro organisms emit hydrolytic enzymes, e.g., cellulose, cellobiase, xylanase, amylase, lipase and protease. A compound consortium of microbes particulates in the hydrolysis and fermentation of untreated material. On the whole of the bacteria are rigorous anaerobes such as Bactericides, Clostridia and Bifidobacteria [61].

6. Biomethanation process and applications

The Bio-methanation process is the essential processes for treating the Bio- degradable portion of Municipal Solid Waste. In this process the organic matter is converted into biogas that is the useful form of energy. In the bio-methanation process, the bio-methanation process reactor, called Bio-digest is used in which the temperature and atmosphere is controlled by the process to occur. Depending on the feedstock, method of operation, volume of the digester, the sternness of health and environmental consequences due to biomethanation that varies considerably.

For energy absorption two-stage digester systems are ideal that consist of a high- loaded chief fermenter and a low-loaded secondary fermenter in sequence, that treats the digestate from the primary stage. The evaluation of 61 farm plants has exposed that two-stage digestion results in superior gas yields and a condensed residual methane potential of the digester [62]. A classic flow chart of a two-stage plant is shown in Fig. 2 [68].

In two-stage digestion, hydrolysis and methanation takes place in both reactors. For achieving an improved metabolization of solid untreated compounds into readily biodegradable carbonic acids, the function of two-phase reactors with a detach hydrolysis stage are advantageous, since the ideal pH range for hydrolysis (5.5–6.5) and methanation (6.8–7.2) is different [63–64]. A drawback of two-phase digestion is the complicated control of process and process parameters. In a broken hydrolysis stage, methane and hydrogen can be formed in an outsized extent, that causes energy losses and has a negative atmosphere effect when the hydrolysis gas is emitted to the atmosphere [65]. Therefore, a gas tight casing of the hydrolysis fermenter is usually necessary to avoid energy losses and emissions of climate significant gases and stinking substances.

Almost wet fermenters are operated at mesophilic temperatures with optima values of 38 and 42 °C, and few biogas plants use thermophilic circumstances on 50 and 55 °C. At higher temperatures, the squalor rate is faster, and thus, shorter HRTs and minor reactor volumes are required and the essential methane yield from organic stuff is not influenced. Decreasing the temperature to 50 °C or below reduce the toxicity of ammonia, but the expansion rate of the thermophilic microorganisms that falls

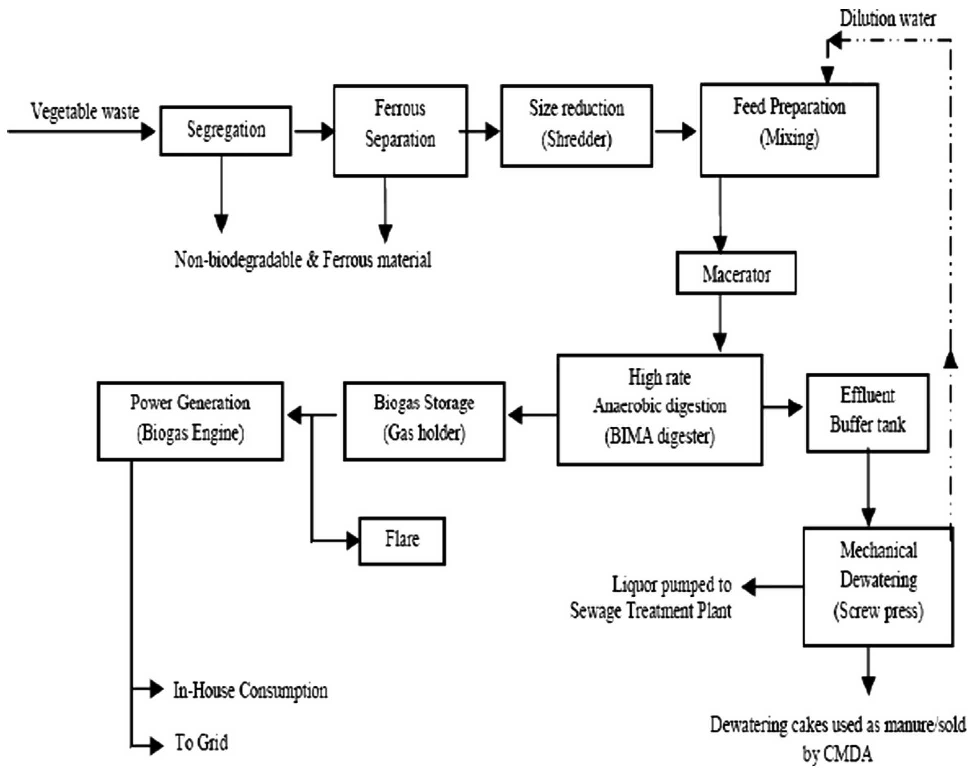

Fig. 2. Process flow diagram [68].

drastically, and a peril of washout of the microbial population is capable of occur, a growth rate inferior at actual HRT [66].

7. Conclusions

The traditional role of agriculture in energy supply was lost in the more recent past, when petrol / diesel driven vehicles replaced horses. Biomass used to be the main source of energy up to the early 20th century. The other things needed daily, e.g. food, fodder, fertiliser, fibres etc., have also been derived from biomass. With the progressive depletion of fossil raw materials, biomass again become an important raw material, both for material- and energy production. Microbial energy conversion processes, e.g. biogas production, offer several substantial advantages.

In many countries worldwide anaerobic digesters are used to generate CH_4 in the form of biogas as a source of energy with modern generating technology. Conventional biogas is not completely eco-friendly. The energy exchange plant has resulted into 80% turn down in CHG emissions by this measure of waste, capturing of methane utilization for the generation of electricity. The benefits associated with biomethanation are many and are well known. The use of biogas for cooking and lighting in rural areas and drastically reduce the depletion of natural resources on forests. However, in the absence of a proper technological upgradation, operation and management, this valuable technology become a source of environmental problem both at local level and of global magnitude. This paper concludes that the scope was to develop a biomethanation process for recycling the market waste properly. The native biomethanation technology was the starting point of view of cleanness and suitability to ambient Indian conditions. The proposed process technologies are to construct, and simple to sustain, at the hands of the availability in places. The automation was kept at the tiniest possible level about to reduce energy inputs in the operation. The aim was 10% of the generated energy in the developed operation. The profitable viability was to be an important reflection. The organization of waste in a clean exceptional process that give a location friendly solution to the pollution problem.

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